PhytoKeys 130: 217–224 (2019)
doi: 10.3897/phytokeys.130.34625
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Spiradiclis tubiflora (Rubiaceae), a new cave-dwelling species from southern China

Lei Wu[1], Bing-Mou Wang[2], Bo Pan[3], Xun-Lin Yu[1]

1 *College of Forestry, Central South University of Forestry and Technology, Changsha 410004, China* **2** *Panyu Central Hospital, Guangzhou, 511400, China* **3** *Guangxi Institute of Botany, Guangxi Zhuang Autonomous Region and the Chinese Academy of Sciences, Guilin 541006, Guangxi, China*

Corresponding author: *Xun-Lin Yu* (csfuyuxl@163.com)

Academic editor: *Cai Jie* | Received 18 March 2019 | Accepted 24 May 2019 | Published 29 August 2019

Citation: Wu L, Wang B-M, Pan B, Yu X-L (2019) *Spiradiclis tubiflora* (Rubiaceae), a new cave-dwelling species from southern China. In: Cai J, Yu W-B, Zhang T, Li D-Z (Eds) Revealing of the plant diversity in China's biodiversity hotspots. PhytoKeys 130: 217–224. https://doi.org/10.3897/phytokeys.130.34625

Abstract

Spiradiclis tubiflora, a new Rubiaceae species, is described from a limestone area of southern China. It is similar to *Spiradiclis glandulosa* and *S. umbelliformis*, but differs from the latter two in its linear stipule, short peduncle and tubular-funnelform corolla with a distinctively enlarged tube. The colour photograph, illustrations, detailed descriptions and conservation status of the new species are provided.

Keywords

Rubiaceae, taxonomy, Guangdong, limestone

Introduction

Caves are considered to be extreme and exceptional habitats that usually provide insufficient resources, especially lack of light, water and soil for plants to survive (Whitten 2009). Most caves are isolated environments which lead to the limitation in dispersal or movement of species and provide great possibilities for speciation and radiation (Biswas 2009, Chung et al. 2013). Many cave-dwelling species, especially those from karst

Copyright *Lei Wu et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

areas, are highly localised (Chen 2006, Whitten 2009). Recently, the number of newly discovered and described plant species with unique characters from China's karst caves is increasing dramatically, including *Begonia* L. (Begoniaceae, e.g. Peng et al. 2012), *Chiritopsis* W. T. Wang (Gesneriaceae, e.g. Wu et al. 2011), *Elatostema* J.R.Forster & G.Forster (Urticaceae, e.g. Fu et al. 2017), *Lagarosolen* W. T. Wang (Gesneriaceae, e.g. Xu et al. 2011), *Pilea* Lindl. (Urticaceae, e.g. Monro et al. 2012) and *Polystichum* Roth (Dryopteridaceae, e.g. Han et al. 2016). *Spiradiclis* Blume also exhibits a great diversity in cave habitat with six newly published species from karst caves (Deng et al. 2014, Wen et al. 2015, Wu et al. 2015a, 2015b, 2016, Liu et al. 2018).

There are approximately 53 *Spiradiclis* species worldwide, most representatives being herbs and occurring in limestone areas (Chen and Taylor 2011, Deng et al. 2014, Wang et al. 2015, Wen et al. 2015, Wu et al. 2015a, 2015b, 2016, 2019, Wang 2016a, 2016b, Pan et al. 2016, 2019, Liu et al. 2018). China is the diversity centre of *Spiradiclis* with 47 species being recorded and most of them distributed in Guangxi and Yunnan provinces of south-western China (Lo 1999, Chen and Taylor 2011, Liu et al. 2018, Pan et al. 2019).

Spiradiclis is a taxonomically difficult genus and most similar to *Ophiorrhiza* L. (Chen and Taylor 2011), some specimens of *Spiradiclis* and *Ophiorrhiza* with flowers have even been frequently misidentified with each other (Wu et al. 2015a). However, *Spiradiclis* can be distinguished from *Ophiorrhiza* by its linear-oblong or subglobose capsules with two or four valves when mature (vs. obcordate and compressed capsules with two valves when mature) (Lo et al. 1983, Robbrecht 1988, Lo 1999, Chen and Taylor 2011). The genus was split into two subgenera: subgenus *Spiradiclis* characterised by ellipsoid to linear-oblong capsules with twisted valves when mature and subgenus *Sinospiradiclis* H.S.Lo characterised by subglobose capsules with untwisted valves (Lo 1998).

During a field investigation of the karst cave in Guangdong Province, southern China in 2009, a peculiar species of Rubiaceae was found. The plant has subglobose capsules, dehisces with four valves and many small, granulate seeds when mature (Figs 1F, 2I) which clearly indicated it belongs to *Spiradiclis*. After re-collections of flowers and fruit materials and further comparison of the known *Spiradiclis* species, we confirmed that it is an unpublished species and report it here.

Material and methods

Materials are deposited at the herbarium of forest plants in Central South University of Forestry and Technology (CSFI), Guangxi Institute of Botany, Guangxi Zhuang Autonomous Region and Chinese Academy of Sciences (IBK). Morphological observations and measurements of the new species are based on living material in the field, as well as dry specimens. The conservation status of the new species is evaluated, based on field observations in accordance with IUCN guidelines (2016).

Taxonomic treatment

***Spiradiclis tubiflora* L.Wu, B.M.Wang & B.Pan, sp. nov.**
urn:lsid:ipni.org:names:60479355-2
Figs 1, 2A–I

Diagnosis. This species is similar to *Spiradiclis glandulosa* and *S. umbelliformis* by having procumbent to creeping habit. It is, however, easily distinguished from the latter two by its linear stipule, short peduncle and tubular-funnelform corolla with distinctively enlarged tube.

Type. China. guangdong: Yingde city, Jiulong town, on the wall near the mouth of a karst cave, 460 m alt., 24°17'N, 112°36'E, 18 Oct 2016 (flower), B. Pan GX-IBPB2016023 (holotype: IBK!; isotype: CSFI!)

Description. Herbs to 5 cm in height, perennial, procumbent to creeping; stems glabrous or subglabrous. Petiole 0.3–1.8 cm, sparsely pubescent; leaf blade drying papery, adaxially green, abaxially pale, ovate to elliptic, 4.5–25.5 × 4.0–14.5 mm, both surfaces pubescent, abaxially with densely yellow glandule-like spots, base rounded to obtuse, sometimes decurrent, apex acute to rounded; secondary veins 3–5 pairs; stipules usually caduceus, pubescent, narrowly linear, 3–5 mm long. Inflorescences cymose, umbelliform to subcapitate, 2–5-flowered; peduncles 1.2–1.5 cm long, densely pubescent; bracts subulate, densely pubescent, 1.8–3.0 mm long; pedicels 1.5–2.0 mm long. Calyx densely pubescent; hypanthium portion subglobose, 1.4–1.6 mm long; lobes triangular, 1.4–1.6 mm long. Corolla white, tubular-funnelform, subglabrous outside; tube 14–16 mm long, ca. 2 mm in diameter at the base, while 3.8–4.5 mm in diameter at the middle of corolla tube, inside densely pubescent near base; lobes ovate to ovate-triangular, 3.5–4.5 × 2.5–3.0 mm. Stamens 5, inserted at the middle of corolla tube; filaments 0.5–1.5 mm long; anthers dorsifixed, linear. Ovary 2-celled, ovules numerous in each cell on peltate axile placentas, attached to the middle of the septum; stigmas 2-lobed, appearing near the throat of corolla tube. Capsules subglobose, ca. 2 mm in diam., densely pubescent, valves 4. Seeds many, dark brown, granular, 0.22–0.28 mm long.

Distribution and ecology. The new species is only known from the type locality. Plants on the wall or large stones inside or at the mouth of the cave, usually wet and covered with calcareous soil. Flowering from August to October, occasional few individuals in March to May, fruiting from September to December.

Etymology. The specific epithet refers to the corolla shape of the new species. The Chinese name is given as "cu-tong-luo-xu-cao (粗筒螺序草)".

Preliminary conservation status. Up to now, only one population with 360 individuals have been found in the type locality. Although five field investigations have been carried out in the surrounding area of the type locality in the past five years since the new species was discovered, no additional populations have been found. The individuals are occurring in places with thick calcareous soil and thriving in low-light conditions. Karst caves are known for their spectacular landscape and nature which

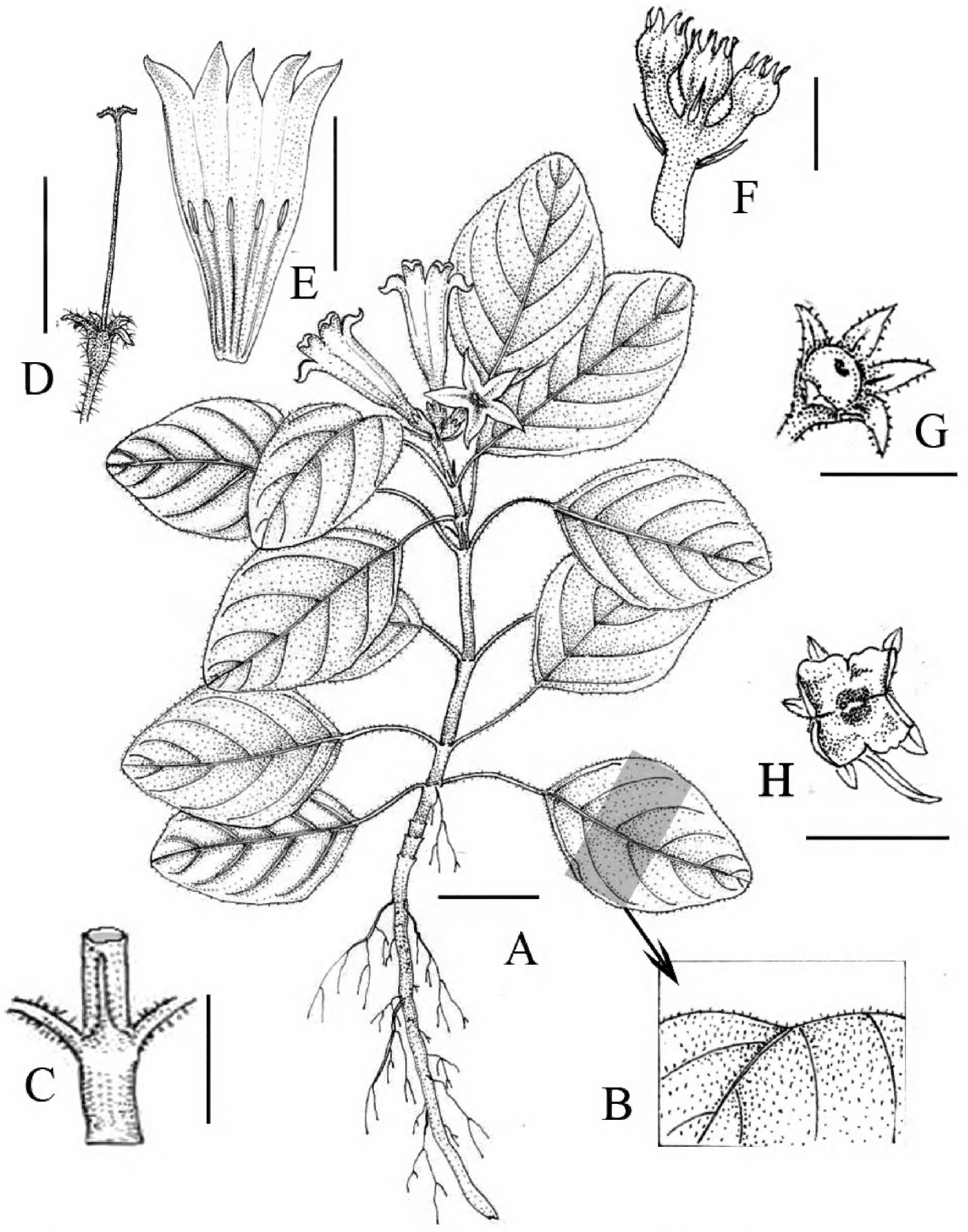

Figure 1. *Spiradiclis tubiflora*. **A** Habit **B** Enlarged leaf blade (adaxial) **C** Stipule **D** Style **E** Opened corolla **F** Infructescence, lateral view **G** Capsule before dehiscence **H** Matured capsules split into four valves. Scale bars: 1 cm (**A, D, E**); 3 mm (**C, F–H**). Drawn from the holotype by Zheng-Meng Yang.

attract tourists. Many karst caves in China played an important role in stimulating the local economy and were exploited for tourism. The cave where the new species occurred has not been spared and the cement road has been built directly leading into the cave, despite this cave being located far away from human settlements. According to the IUCN (2016) Red List Categories and Criteria, *Spiradiclis tubiflora* should be assigned as Critically Endangered (B2ab(iii,iv,v) & D).

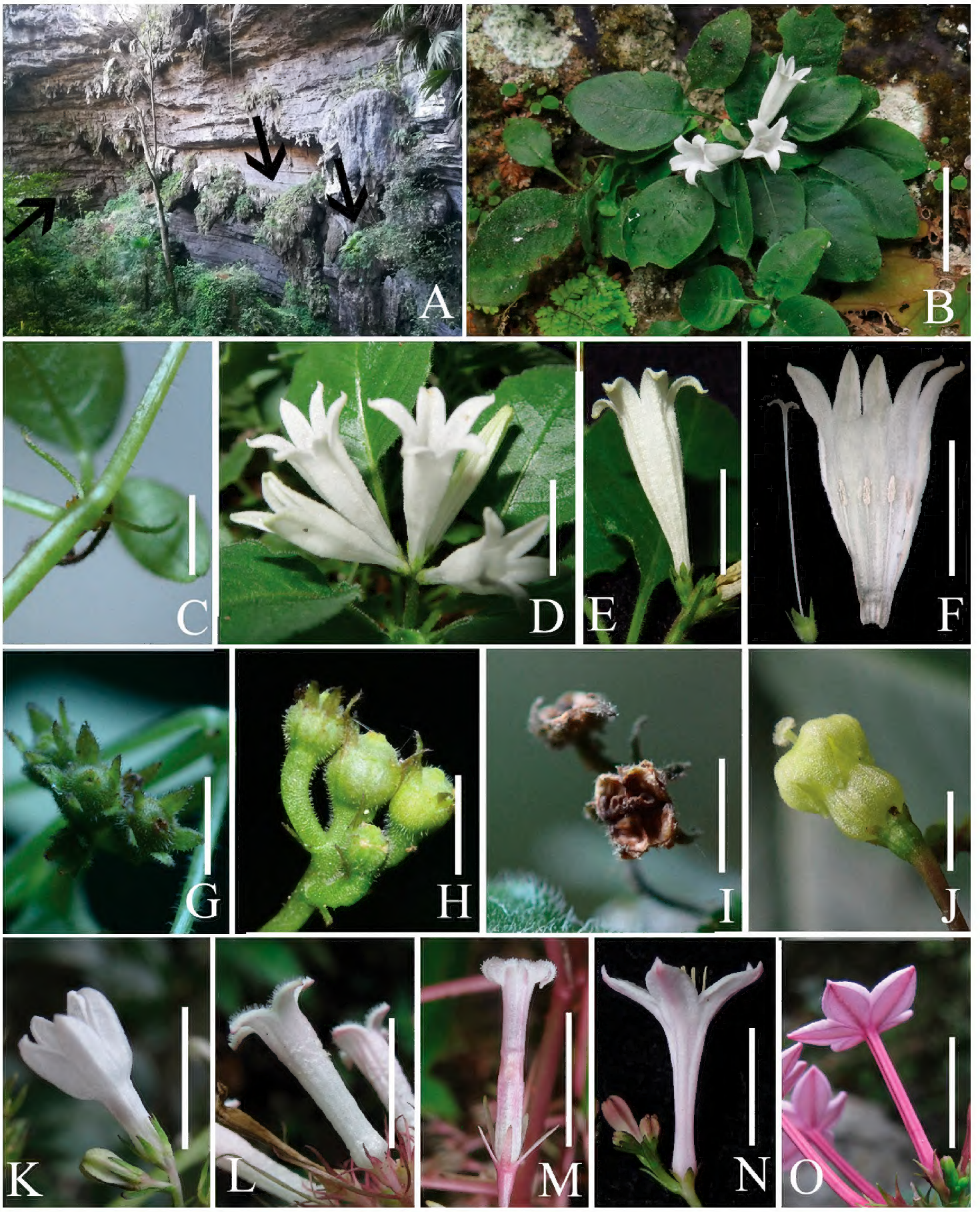

Figure 2. *Spiradiclis tubiflora*. **A** Habitat (the arrow shows the place of growth) **B** Habit **C** Stipule **D** Inflorescence, lateral view **E** Flower, lateral view **F** Corolla opened to show floral parts **G** Capsules, frontal view **H** Capsules, lateral view **I** Matured capsules with four valves. Flowers of selected Spiradiclis species, lateral views: **J** *S. longipedunculata* **K** *S. fusca* **L** *S. malipoensis* **M** *S. baishaiensis* **N** *S. glabra* **O** *S. coccinea*. Scale bars: 1 cm (**B, D, E, F, K, L, M, N, O**); 3 mm (**C, G, H, I, J**). Photos by Bo Pan, Jing Liu and Lei Wu.

Discussion. The corolla character of *Spiradiclis* shows great diversity (Fig. 2J–O). The corolla tube of the genus ranges from 2.5 to 24 mm (Chen and Taylor 2011), the corolla colour appears in white, pink or purple-reddish and the corolla shape varies

Table 1. Morphological comparison of *Spiradiclis tubiflora*, *S. glandulosa* and *S. umbelliformis*.

	Spiradiclis tubiflora	***S. glandulosa***	***S. umbelliformis***
Stipule	narrowly linear, usually caduceus	deeply 2-parted, persistent	deeply 2-parted, persistent
Peduncle	1.2–1.5 cm long	2–5 cm long	2–7 cm long
Calyx lobe	triangular, 1.4–1.6 mm long	oblong-lanceolate, ca. 4–6 mm long	ovate-triangular, ca. 0.6 mm long
Corolla	tubular-funnelform	funnelform	funnelform to tubular-funnelform
Corolla tube	14–16 mm long, enlarged distinctly, 3.8–4.5 mm in diam. at middle	16–18 mm long, slender, ca. 1.8 mm in diam. at middle	17–18 mm long, slender, ca. 1.5 mm in diam. at middle

from urceolate-tubular (*Spiradiclis longipedunculata* S. Y. Liu & S. J. Wei, Fig. 2J), tubular (*S. malipoensis* H. S. Lo, Fig. 2L and *S. baishaiensis* X. X. Chen & W. L. Sha, Fig. 2M), funnelform (*S. fusca* H. S. Lo, Fig. 2K and *S. glabra* L. Wu & Q. R. Liu, Fig. 2N) to salverform (*S. coccinea* H. S. Lo, Fig. 2O). Although the corolla shape of *Spiradiclis tubiflora* is tubular-funnelform, its corolla tube enlarges distinctly from near the base to the throat of the corolla which currently is unique in all the known *Spiradiclis* species (Fig. 2D, E). *Spiradiclis tubiflora* is morphologically most similar to *S. glandulosa* L. Wu & Q. R. Liu and *S. umbelliformis* H. S. Lo by having procumbent to creeping habit, but it can be distinguished from the latter two species (Table 1). According to Lo (1998), this new species belongs to subg. *Sinospiradiclis* on the basis of its subglobose capsules with four untwisted valves (Figs 1E–G, 2G–I).

Based on our field investigations of *Spiradiclis* in China and careful studies of relevant literature and specimens, about 94% of the known *Spiradiclis* species are confirmed to be distylous plant, of which more than 30 species have been observed with both long- and short-styled flowers in the same population. It is known that being distylous is a unique phenotype in plants to ensure reproduction by avoiding self-pollination and to increase male fitness and outcrossing rates by reducing sexual interference between male and female functions (Watanabe et al. 2017). In this study, however, all the individuals with observed flowers are with stamens inserted at the middle of the corolla tube and stigmas located near the throat of the corolla tube, this being the long-styled form. This phenomenon could be interpreted from two aspects currently: 1) both styled flowers are present in the population but only few individuals are short-styled rather than long-styled and they could be overlooked during the investigations; 2) this population is a monomorphic population with all individuals having long-styled flowers which is not rare and was reported from other groups such as *Eichhornia* Kunth and *Luculia* Sweet (Barrett 1989, Zhou and Wang 2009). Further studies on the reproductive and pollination biology of the new species are needed.

Specimens examined (Paratypes). CHINA. Guangdong: the type locality, 27 Nov 2016 (fruit), L. Wu & B. M. Wang 5610 (CSFI!), 13 Oct 2017, L. Wu & B. M. Wang 6236 (CSFI!).

Acknowledgements

Authors are grateful to the staff of HN, IBK, IBSC, KUN and PE for permission to examine their specimens. We also thank Zheng-Meng Yang for his excellent drawing and Jing Liu for helping us to prepare the colour figure. This study was supported by the National Nature Foundation of China (project no. 31600160).

References

Barrett SCH (1989) Waterweed invasions. Scientific American 261(4): 90–97. https://doi.org/10.1038/scientificamerican1089-90

Biswas J (2009) The biodiversity of Krem Mawkhyrdop of Meghalaya, India, on the verge of extinction. Current Science 96: 904–910.

Chen T, Taylor CM (2011) Rubiaceae. In: Wu ZY, Hong DY, Raven PH (Eds) Flora of China. Vol. 19. Science Press, Beijing & Missouri Botanical Garden Press, St. Louis, 330–339.

Chen WH (2006) An outline of speleology research progress. Dizhi Lunping 52: 783–791. [In Chinese]

Chung K, Huang H, Peng C, Xu WB (2013) *Primulina mabaensis*, (Gesneriaceae), a new species from a limestone cave of northern Guangdong, China. Phytotaxa 92(2): 40–48. https://doi.org/10.11646/phytotaxa.92.2.2

Deng SJ, Wen HZ, Huang XX, Wang RJ (2014) *Spiradiclis coriaceifolia* and *S. tonglingensis*, spp. nov. (Rubiaceae, Ophiorrhizeae) from Guangxi, China. Nordic Journal of Botany 5(5): 594–601. https://doi.org/10.1111/njb.00461

Fu LF, Monro AK, Huang SL, Wen F, Wei Y-G (2017) *Elatostema tiechangense* (Urticaceae), a new cave-dwelling species from Yunnan, China. Phytotaxa 292(1): 85–90. https://doi.org/10.11646/phytotaxa.292.1.9

Han MQ, Liu Y, Zhang LB (2016) Seven new species of *Polystichum* (subg. *Haplopolystichum*; Dryopteridaceae) from southern China. Phytotaxa 280(3): 201–221. https://doi.org/10.11646/phytotaxa.280.3.1

IUCN (2016) Guidelines for Using the IUCN Red List Categories and Criteria. Version 12. Prepared by the Standards and Petitions Subcommittee. http://www.iucnredlist.org/documents/RedListGuidelines.pdf [accessed: 18 March 2019]

Liu J, Pan B, Li SW, Xu WB (2018) *Spiradiclis quanzhouensis* (Rubiaceae): A new species from limestone area in Guangxi, China. Nordic. Le Journal de Botanique: 01595. https://doi.org/10.1111/njb.01595

Lo HS (1998) Materials for Chinese Rubiaceae (IV). Bulletin of Botanical Research 18: 275–283. [In Chinese]

Lo HS (1999) *Spiradiclis* Blume. In: Lo HS (Ed.) Flora Reipublicae Popularis Sinicae. Vol. 71 (1). Science Press, Beijing, 86–110.

Lo HS, Sha WL, Chen XX (1983) A revision of the genus *Spiradiclis* Bl. Acta Botanica Austro Sinica 1: 27–36. [In Chinese]

Monro A, Wei YG, Chen CJ (2012) Three new species of *Pilea* (Urticaceae) from limestone karst in China. PhytoKeys 19(0): 51–66. https://doi.org/10.3897/phytokeys.19.3968

Pan B, Ma HS, Wang RJ (2016) *Spiradiclis pengshuiensis* (Ophiorrhizeae, Rubioideae), a new species from Chongqing, China. PhytoKeys 63: 41–45. https://doi.org/10.3897/phytokeys.63.8016

Pan B, Tu RH, Hareesh VS, Wu L (2019) *Spiradiclis cavicola* (Rubiaceae), a new species from Limestone Caves in Southwestern China. Annales Botanici Fennici 56(1–3): 1–4. https://doi.org/10.5735/085.056.0101

Peng CI, Ku SM, Kono Y, Liu Y (2012) *Begonia chongzuoensis* (sect. *Coelocentrum*, Begoniaceae), a new calciphile from Guangxi, China. Botanical Studies (Taipei, Taiwan) 53: 285–292.

Robbrecht E (1988) Tropical woody Rubiaceae. Opera Botanica Belgica 1: 599–602.

Wang RJ (2016a) *Spiradiclis jingxinensis* sp. nov. (Rubiaceae) from Guangxi, China. Nordic Journal of Botany 34(5): 550–552. https://doi.org/10.1111/njb.01134

Wang RJ (2016b) *Spiradiclis yangchunensis* (Rubiaceae), a new species from Guangdong, China. Zhiwu Kexue Xuebao 34: 13–17.

Wang RJ, Wen HZ, Deng SJ, Zhou LX (2015) *Spiradiclis danxiashanensis* (Rubiaceae), a new species from South China. Phytotaxa 206(1): 30–36. https://doi.org/10.11646/phytotaxa.206.1.5

Watanabe K, Kato H, Kuraya E, Sugawara T (2017) Pollination and reproduction of *Psychotria homalosperma*, an endangered distylous tree endemic to the oceanic Bonin (Ogasawara) Islands, Japan. Plant Species Biology 33(1): 16–27. https://doi.org/10.1111/1442-1984.12183

Wen HZ, Wang RJ, Deng SJ (2015) *Spiradiclis longanensis*, a new species of Rubiaceae from China. PhytoKeys 55: 113–117. https://doi.org/10.3897/phytokeys.55.4975

Whitten T (2009) Applying ecology for cave management in china and neighbouring countries. Journal of Applied Ecology 46(3): 520–523. https://doi.org/10.1111/j.1365-2664.2009.01630.x

Wu L, Wang JL, Liu QR (2015a) *Spiradiclis pauciflora* (Rubiaceae), a new species from limestone areas in Guangxi, China. Annales Botanici Fennici 52(3–4): 257–261. https://doi.org/10.5735/085.052.0318

Wu L, Wang JL, Mo SS, Liu QR (2015b) *Spiradiclis glandulosa* sp. nov. (Rubiaceae) from limestone areas in southern China. Nordic Journal of Botany 33(1): 79–82. https://doi.org/10.1111/njb.00577

Wu L, Tong Y, Pan B, Liu QR (2016) *Spiradiclis glabra* sp. nov. (Rubiaceae) from limestone area in Guangdong, China. Nordic Journal of Botany 34(6): 718–721. https://doi.org/10.1111/njb.01156

Wu L, Li X, Liu WJ, Liu QR (2019) *Spiradiclis karstana* (Rubiaceae), a new species from Yunnan, China. PhytoKeys 117: 1–8. https://doi.org/10.3897/phytokeys.117.28281

Wu WH, Xu WB, Wu L (2011) *Chiritopsis hezhouensis* (Gesneriaceae) from karst caves in Guangxi, china. Taiwania 56: 132–137.

Xu WB, Gao HS, Liu Y (2011) *Lagarosolen jingxiensis* Yan Liu, H S.Gao & W.B.Xu, a new species of Gesneriaceae from Guangxi, China. Redai Yaredai Zhiwu Xuebao 16: 274–276.

Zhou W, Wang H (2009) Heterostyly in angiosperms and its evolutionary significance. Zhiwu Xuebao 44: 742–751. [In Chinese]